and the temperature usually does not fall appreciably during the first hour or two after that time. Minimum temperatures generally occur at sunrise or a few minutes afterward, and on clear mornings a rapid rise begins about half an hour after that time.

With the thermograph record-sheets for the entire 6½ years available, daily maximum and minimum temperatures were extracted for 24-hour periods ending at the four times mentioned above, and monthly means were computed from these data. The maxima obtained for the period ending at 8 a. m. were in all cases charged to the preceding day. These extremes were considered to be observation readings of maximum and minimum thermometers made at these times. No instrumental corrections were applied, as instrumental error would have the same effect on all values, and therefore not affect the differences. The rapid rise in temperature, which on clear mornings begins about half an hour after sunrise, made an excellent time check, as practically all sheets showed at least two or three such mornings, and most of them more than that. Most of the time, however, the thermograph was found to be running on time, or very close to it. After the monthly means were computed, means for all months of the same name and time of observation were computed, and then the differences between the mean obtained by observations taken at each of the three times during the day and the midnight standard. As sunset occurs close to 5 p. m. during the months of November, December, and January, the 5-p. m. values were used for sunset also during these months.

Table 1 shows the variation in mean temperature from the midnight-to-midnight standard produced by taking the observations at the other three times named above. All available data were used in its preparation, and it is believed that if longer records had been available, the results would not have been materially different.

Because the maximum temperature occurs so late in the afternoon in Idaho, observers who take their readings at 5 p. m., do so at approximately the same time that the maximum occurs during 7 months of the year; and during the other 5 months, the temperature has fallen only a little from the maximum by that hour. Therefore 1 warm day would result in 2 high maximum readings, one on the warm day, and the other on the next; while 1 cold night would result in only 1 low minimum reading being recorded. The sunset reading gives better results, but still shows a considerable number of carry-over maxima, and gives a mean temperature considerably higher than the midnight standard for all months of the year. The 8 a. m. and midnight values are very near the same for all months except February. In most cases, the carry-over minimum readings obtained by taking observations at 8 a. m. are offset by minimum temperatures occurring at midnight, each instance resulting in 2 low readings for 1 cold night; and 1 warm day in either case would give only 1 high maximum reading. Except in the winter, the temperature usually rises so much by 8 a. m. that there are few carry-over minima.

TABLE 1.—*Departure from midnight-to-midnight mean temperature obtained by taking observations at other times of the day (degrees Fahrenheit)*

Time of observation	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
5 p.m.	+1.0	+1.0	+1.1	+1.5	+1.3	+1.4	+1.2	+1.1	+1.4	+1.2	+1.0	+0.9	+1.2
Sunset	+1.0	+.4	+.5	+.6	+.5	+.4	+.3	+.3	+.4	+.6	+1.0	+.9	+.6
8 a.m.	−.3	−.6	−.2	+.2	0	+.2	+.3	+.1	−.1	−.2	−.3	0	−.1

From this table of differences between the midnight-to-midnight standard and mean temperatures obtained by taking readings at the other times of the day, it is evident that mean temperatures based on afternoon observations, especially if taken as early as 5 p. m., are considerably too high to be comparable with those based on the Weather Bureau standard of midnight-to-midnight, or the 8 a. m. readings; and that if it is desired to have cooperative readings that are comparable to regular Weather Bureau station records, observations taken at 8 a. m. will give the best results of any practicable time. It is impossible, of course, to obtain records based on the midnight-to-midnight period except at regular Weather Bureau stations. If for any reason it is necessary for a cooperative observer to take his readings during regular working hours (from 8 a. m. to 5 p. m.) the early morning hour will result in mean temperatures much more comparable with those recorded at a regular Weather Bureau station than if the observation is taken in the afternoon. It is recognized that difficulty is frequently experienced in determining the date on which maximum temperatures occur when based on morning observations, as some observers set them back 1 day and others do not; but it is believed that the advantages in obtaining records which are more nearly comparable with those made at regular Weather Bureau stations will more than offset this minor difficulty.

THE USE OF FREE-AIR SOUNDINGS IN GENERAL FORECASTING

By HORACE R. BYERS

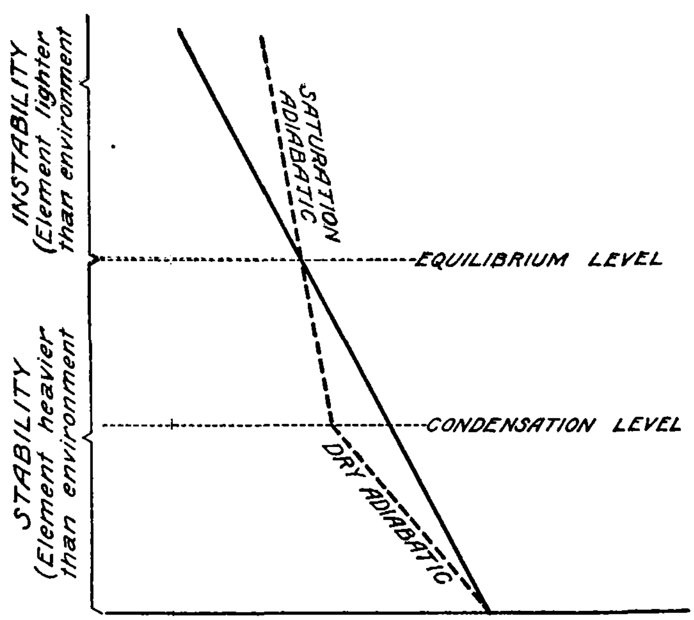
The use of free-air soundings in general forecasting practice presents several difficulties, chief of which is the limited time allowed for analysis of the data. With a score or more of aeroplane sounding stations dotting the country, enough information should be available for approximating mathematical treatment of the forecast problem; but to utilize in this manner all of the data to their fullest extent is a task left to the research worker, who calculates the atmospheric conditions after the weather events have taken place. In the office of a weather service such as the United States Weather Bureau, less than 2 hours are allowed between the time the data of upper air soundings are received and the general forecasts are issued, so that no time is available for detailed analysis.

However, in this limited time much can be accomplished through the use of rapid graphical methods for determining the state of the atmosphere. Recent advances in the graphical representation of air-mass properties and new knowledge concerning the behavior of the upper air have been helpful. In the course of nearly a year's work in practical forecasting with the use of these data for most of the United States, the writer has found a highly satisfactory degree of success possible without the expenditure of a great deal of time.

Since superadiabatic lapse rates are rare and of little consequence in the free atmosphere, we need consider only instability with respect to saturated air in forecasting rain and storms. This, of course, assumes that we accept the principles of modern synoptic meteorology that heavy clouds and precipitation are formed almost exclusively by adiabatic cooling of moist air during upward motions; and that departures from equilibrium conditions in the vertical temperature distribution, to which we give the name instability, are the determining factors in these vertical movements. For fogs and stratus clouds, such as those which are so prevalent in California, other cooling processes are of importance, for example, cooling by contact with a cold ocean surface or a radiation-cooled ground surface, and other factors in the vertical temperature curves should be given the principal consideration. In this brief discussion, however, attention is confined to the meteorological conditions for the formation of precipitation, assumed to be a result of adiabatic processes alone.

In general, four factors should be studied in connection with the soundings, as follows: First, the identification of the air masses; second, the changes that are taking place in the air masses as shown by comparison with previous data on the same masses; third, the present state of stability or instability of the air; and fourth, the changes in lapse rate which may be expected, especially if the air is lifted along a front or over large mountain areas.

The first question, that of air-mass identification, has been admirably discussed by Rossby (1) and by Willett



(2). The problem of changes taking place in the air-masses requires that the forecaster note especially the addition or subtraction of heat and moisture to the air-mass, and the development of subsidence, turbulence, and temperature inversions.

To test the present state of stability or instability of the air-mass, the Refsdal chart or Neuhoff diagram should be used, and the test made for what Refsdal has called conditional instability. The test consists of tracing the pressure-temperature or altitude-temperature curve of a rising element of the air which contains moisture but is not saturated. The dry adiabatic rate of cooling of 1° C. per 100 meters will be followed until saturation is reached, after which the air will cool at the slower saturation or moist adiabatic rate. If the prevailing lapse rate in the surrounding atmosphere is between the dry and saturation adiabatic rates, an element lifted upward would first encounter resistance to its vertical motion, because it would cool with altitude at the faster dry adiabatic rate; after condensation, it would follow the saturatinn adiabatic rate, which is slower than that of the surrouoding atmosphere, and pass from stable to unstable, that is, from heavier to lighter than its surroundings (fig. 1). This type of temperature distribution is called conditional instability, the conditions being (1) a sufficient amount of moisture in the air so that the moving element becomes saturated soon enough to follow a saturation adiabatic line which intersects the prevailing lapse rate curve, and (2) a strong enough mechanically-produced lifting to overcome the stabilizing forces at the lower levels and carry the element to the equilibrium point.

By tracing on the adiabatic chart the temperature-pressure relationships of an element lifted upward through the air in this manner, we have what is called an emagram, first used by Refsdal. Areas on the chart where the rising element is warmer than its surroundings are called positive areas and are usually shaded red. The parts where the moving air is colder are called negative areas, generally colored blue. The extent of these areas is supposed to be a measure of the convective energy available in the atmosphere. The tephigram, developed by Sir Napier Shaw, shows the same properties of the air, but has the disadvantage that it requires an additional chart.

Numerous objections to the emagram and tephigram and their forecasting value have been made recently. However, in our use of the emagram, we have found it of great value in forecasting instability showers and thunderstorms within an air-mass. It is especially useful in air-masses where these phenomena are likely to occur, such as the Tropical Gulf air.

The changes in the stability characteristics that result from changes in the lapse rate of the air produced in widespread bodily lifting of the air-mass were discussed by Rossby. (1). The characteristic of the air which for moist air makes its lapse rate change radically from stability to instability, Rossby calls convective instability; it has no reference to current stability characteristics of the atmosphere, but represents what one might call potential instability: The instability will materialize only in case the air is lifted and its potentialities thus realized. Rossby proved that convective instability in a layer is definitely indicated simply when the equivalent potential temperature decreases with height within the layer. Thus convective instability can be recognized at a glance on the Rossby or equivalent potential temperature diagram or some adaptation of it. At the Massachusetts Institute of Technology, 2 types of equivalent potential temperature diagrams are printed—1 containing pressures and temperatures of the condensation levels, and 1 without these quantities. For air-mass identification, the latter diagrams are preferable; but to determine the degree of convective instability, the pressure and temperature lines are necessary. The discussion of convective instability and how lifting affects the lapse rate is given in Rossby's apper and will not be repeated here. The fundamental idea is that if a layer of air has a much higher water vapor content at its bottom than at its top, the lower part will reach saturation first as the layer is lifted bodily, and will cool at the slow saturation adiabatic rate; the top, however, will cool at the much faster dry adiabatic rate, until it also becomes saturated. This results in the upper part of the layer becoming relatively much colder than the lower part, because of its faster rate of cooling. The consequence, of course, is a rapid rate of temperature fall with height within the layer, in other words, instability.

In addition to the four factors which have been listed above, it will be helpful in regions where there is a fairly large number of sounding stations, to construct latitudinal and longitudinal cross-sections of the atmosphere.

Namias has suggested cross-sections of potential temperature, which can be drawn very quickly. Since unsaturated air maintains a constant potential temperature during vertical motions, places in the cross-section where the potential temperature lines dip downward would probably represent subsidence (or a transition from a colder to a warmer air mass), and those where the potential temperature lines slope upward would represent zones of rising air (or a transition from a warm to a colder air mass).

To return to the question of time, it has been the experience in TWA that to construct the adiabatic chart and the Rossby diagram requires about 10 minutes with the data received in the present Weather Bureau code. W. H. Clover has developed a code which we use in transmitting the data to forecast centers that do not receive the data from the Government; with the use of this code, which has the same number of characters as the Weather Bureau code, the time for decoding and plotting is cut in half.

With the use of the above-mentioned methods of aerological analysis, it should be possible for the forecaster making general forecasts to use at least half a dozen free air soundings in the forecasting practice without an appreciable sacrifice of time. A routine man in the forecast center could plot the data in half an hour's time and have it ready for the forecaster's inspection when the latter finishes his weather map analysis.

The writer is certain that no organization in the United States has thus far treated free-air soundings with the routine thoroughness practiced in the TWA (Transcontinental Western Air) meteorological organization in the past year; he therefore hopes that these remarks will be taken as the result of the serious application of aerological material to practical forecasting, for both the short periods covered by individual air transport flights and the longer period forecasts similar to the daily Weather Bureau forecast period.

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A REMARKABLE TEMPERATURE AGREEMENT AT A 33-YEAR INTERVAL

By J. B. KINCER and W. A. MATTICE

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In efforts to detect recurrences of a cyclic nature that possibly would serve as a basis for long-range forecasting a great deal of investigational work has been done and many papers published on the question of approximate repetitions in weather conditions at stated intervals of time. Many such cycles have either been claimed outright as more or less definitely established, or have been suggested as probably real and dependable in their recurring phases. However, it appears that when these are subjected to rigid tests they usually in the last analysis carry conviction of fortuity or chance combinations with no assurance of continued conformity in future years.

Most cases of recurrent agreements refer to conditions covering considerable periods of time, such as the average temperature for a month, a season, or a year. With numerous records we naturally would expect to find many cases of conformity when such periods are considered, but it would not be expected to find, except through the rarest of chance, a case in which the temperature distribution from day to day through a couple of months would be in close agreement with identical calendar days for the same period many years before.

However, a remarkable agreement of this character between maximum temperatures during the 1934 extremely hot summer in the interior States and the daily maxima in 1901 for the same period has come to light. The latter also was outstanding for abnormal heat in the area in question.

Attention was first called to this matter by a graph, prepared by the official in charge of the Weather Bureau station at Indianapolis, Ind., and published in the Indianapolis Star, July 25, 1934. The trend agreement from day to day between these summers, 33 years apart, was so striking that other station records were examined to determine how far this conformity extended geographically and for how long a period of time. This search disclosed marked agreement, considering the data in question, over the Ohio Valley, the lower Missouri Valley, and the northern Great Plains, the records, in general, over these regions being in agreement as to this tendency. The four graphs presented as figure 1 show these agreements. They represent the daily maximum temperatures at Cincinnati and Columbus, Ohio, St. Louis, Mo., and Springfield, Ill., covering the period from June 10 to August 17, or somewhat more than 2 months. A remarkable similarity is shown in view of the character of the data they represent—daily maximum temperatures for identical days for the summer of 1934 and for that 33 years earlier. An examination of the graphs shows a fairly uniform rise in temperature for both years from June 10 to around the 20th of July, with a more or less gradual recession of the curves thereafter to the middle of August. In both cases, of course, they ran far above normal.

Outside the central valleys and beyond the dates covered by these graphs, records for the summer show great divergences in this respect, with no conformity. Also, examination of other data during periods of abnormal temperature conditions, such as the 1934 cold February in the Northeastern States with other Februarys of past years disclosed no such day-to-day temperature agreement.

It appears that such remarkable and unexpected similarity in weather records, the very nature of which would seem to demand as explanation fortuitous combinations should serve to impress investigators of weather recurrences with the necessity for extreme caution in accepting concomitancy of records at time intervals, or apparent recurring phases, as definitely establishing progressions of a dependable cyclical nature. In other words, if agreements such as these can occur in daily maximum temperature data for a period of more than 2 months, the probability for chance combinations of various kinds would appear almost limitless when longer unit time periods are involved, such as a season or year.